SMAP Science and Hydros Heritage

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SMAP Mission Workshop
Arlington, VA
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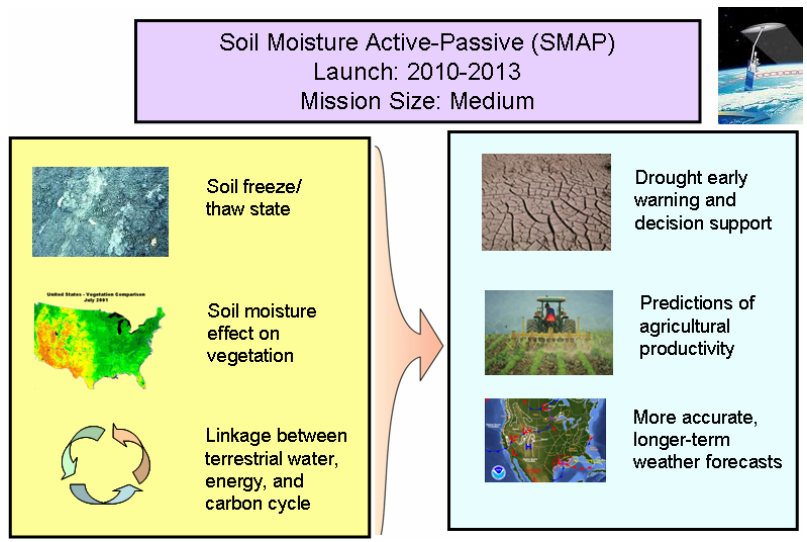
Decadal Survey Panel	Cited Soil Moisture Applications
Water Resources and Hydrological Cycle	1. Floods and Drought Forecasts 2. Available Water Resources Assessment 3. Link Terrestrial Water, Energy and Carbon Cycles
Climate / Weather	1. Longer-Term and More Reliable Atmospheric Forecasts
Human Health and Security	1. Heat Stress and Drought 2. Vector-Borne and Water-Borne Infectious Disease
Land-Use, Ecosystems, and Biodiversity	1. Ecosystem Response (Variability and Change) 2. Agricultural and Ecosystem Productivity 3. Wild-Fires 4. Mineral Dust Production

"…the SMAP mission is ready for "fast-track" towards launch as early as 2012, when there are few scheduled Earth missions. The readiness of the SMAP mission also enables gap-filling observations to meet key NPOESS community needs (soil moisture is "Key Parameter," see 4.1.6.1.6 in IORD-II Document)."

Page 4-43



Panel Recommendations:

Water Resources and Hydrological Cycle Panel:

TABLE 11.1 Candidate Missions in the Order Ranked

Brief Description of Mission	Variables	Type of Sensor(s)	Coverage	Spatial Resolution	Frequency	Synergies with other panels	Related Planned or Integrated Missions (if any)
Soil Moisture and Freeze/ Thaw State	Surface freeze/thaw state; Soil moisture	L-band radar, radiometer	Global	10 km (processed to 1-3 km)	2-3 day revisit	Climate Weather	SMAP Aquarius
Surface Water and Ocean Topography	River and lake elevation; Ocean circulation	Radar altimeter, Nadir SAR interferometer, microwave radiometer, GPS receiver	Global (to ~82° latitude)	Several cm (vertical)	3-6 days	Climate Ecosystems Health Weather	SWOT SMAP GPM NPP/ NPOESS
Snow and Cold Processes	Snow water equivalent; Snow depth; Snow wetness	SAR, Passive microwave radiometry	Global	100 m	3-15 days	Climate Ecosystems Weather	SCLP

Land-Use, Ecosystems, and Biodiversity Panel:

Soil moisture is a key measurement for several disciplines, especially hydrology, where the primary discussion of this mission will be found. We strongly endorse a soil moisture experiment. In order to maximize the value of a soil moisture measurement for ecosystem science, it needs to resolve the time and space scales of variability relevant to ecosystem science. A temporal resolution (repeat sampling interval) of 3-5 days is needed to allow successful assimilation and inference of available water. This time interval is also critical for monitoring the development of plant water limitation and wet intervals associated with rapid and important soil activity. The spatial resolution required must correspond to scales of variability in terrestrial ecosystems, and in the soil moisture anomalies that affect them. This implies spatial resolution on the order of square kilometers to tens of square kilometers.

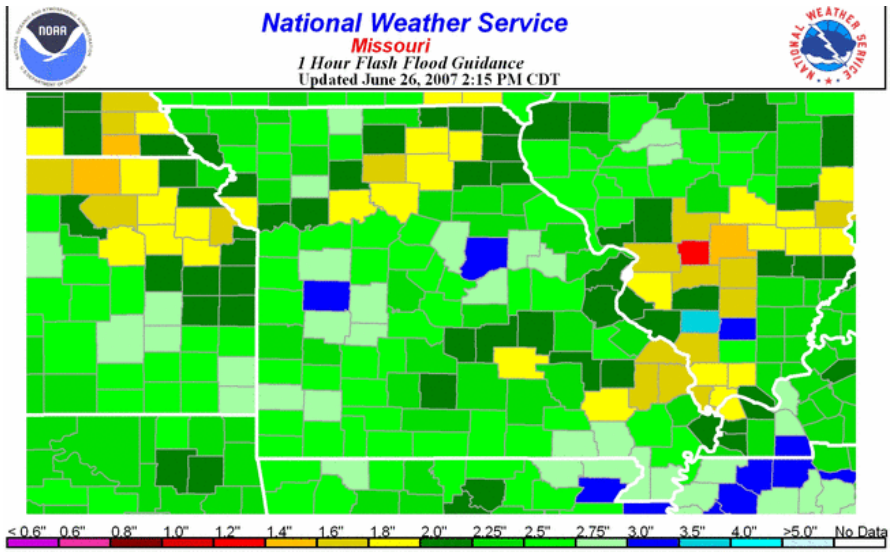
(Page 7-22)

Decadal Survey:

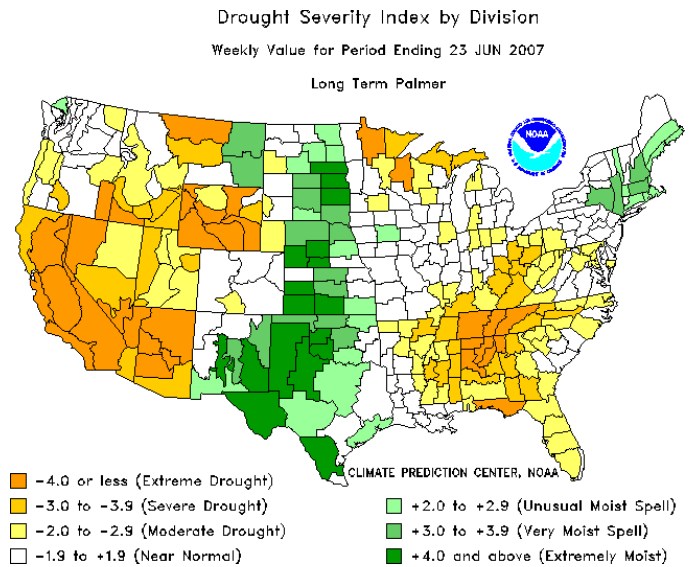
"…delivery of flash-flood guidance to weather forecast offices are centrally dependent on the availability of soil moisture estimates and observations."

"SMAP will provide realistic and reliable soil moisture observations that will potentially open a new era in drought monitoring and decision-support."

Current NWS Operational Flash Flood Guidance (FFG)



Operational Drought Indices of NOAA and National Drought Mitigation Center (NDMC)



Current: Empirical Soil Moisture Indices Using Rainfall and Air Temperature (Counties ~30 km)

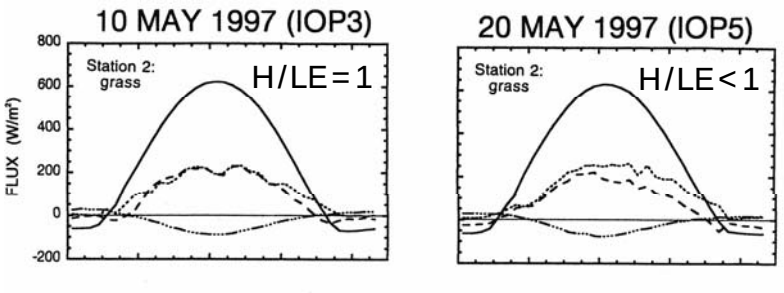
SMAP Soil Moisture Observations at 10 km Resolution

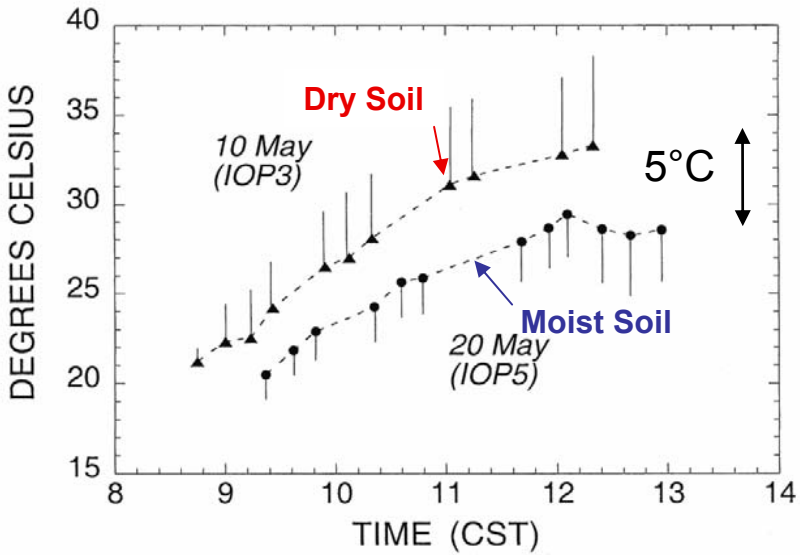
Soil Moisture and Its Impact on Atmosphere

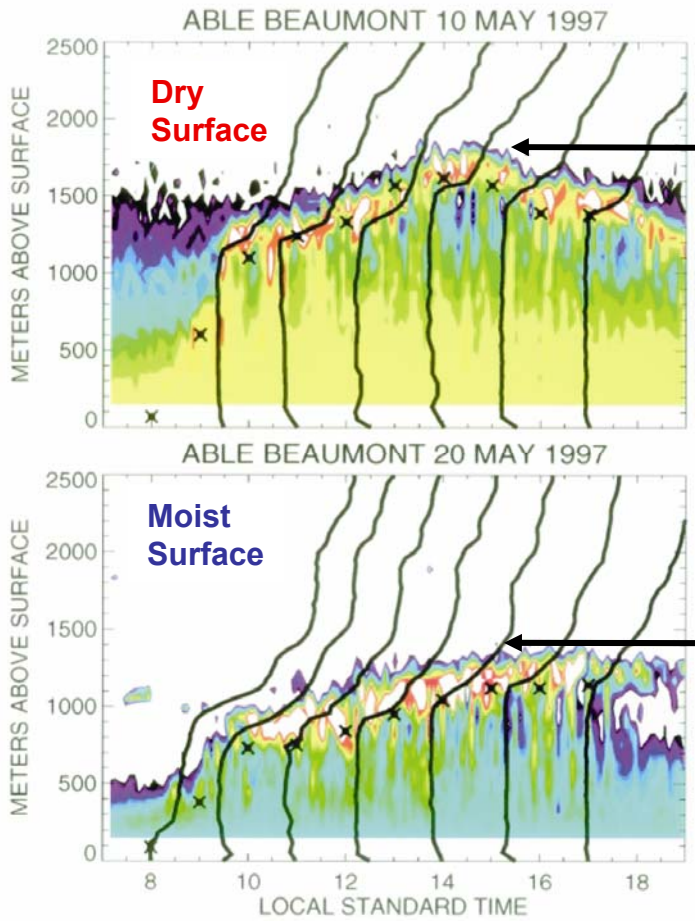
May 10 : Clear with scattered cirrus
PBL Winds 5-7 m/s

May 18: 90 mm Rain

May 20: Clear sky & mild winds

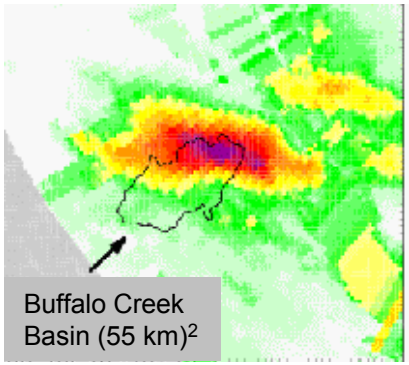






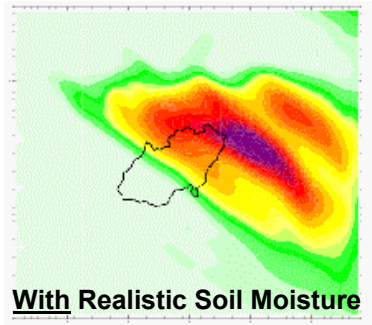
CASES'97, *BAMS* (81), 2000.

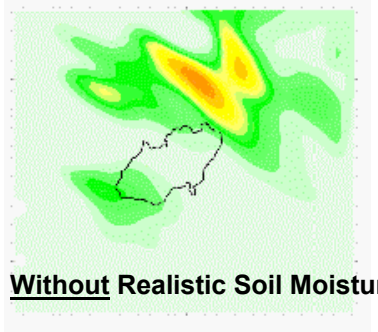
Soil Moisture and Weather Forecasts



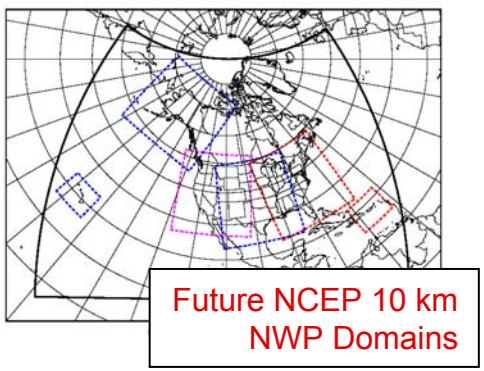
Observed Rainfall
0000Z to 0400Z 13/7/96

24-Hours Ahead Atmospheric Model Forecasts





Chen et al., *JAS* (58) 2001.



"The strong motivation for this land data assimilation and land-monitoring space mission such as HYDROS is that the land states of soil moisture, soil ice, snowpack, and vegetation exert a strong control on ...the heating and moistening of the lower atmosphere…forecast of tomorrow's heat index, precipitation, and severe thunderstorm likelihood."

Louis Uccellini, NCEP

"The experience of the last ten years at ECMWF has shown the importance of soil moisture...Soil moisture is a major player on the quality of weather parameters such as precipitation, screen-level temperature and humidity and low-level clouds."

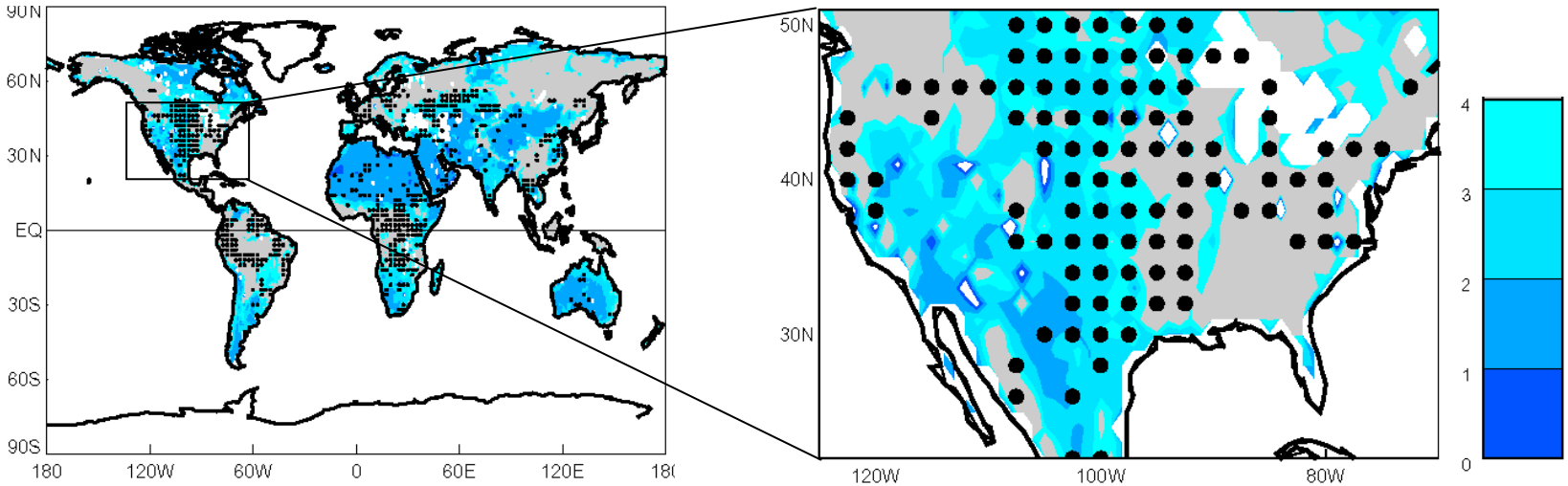
Anthony Hollingworth, ECMWF

Soil Moisture and Climate Prediction

Regions Where Soil Moisture Has Significant* Impact on Seasonal Precipitation Predictability Through Land-Atmosphere Coupling (Dots)

Product Retrieval Error Map (Blue Shades in % Volumetric)

Koster et al. 2003, *J. Hydromet. 4[2]*)

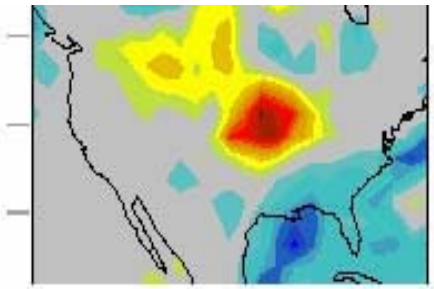


*At Least 1 in 5 Summers Affected in Model Simulations

Response From Multiple Climate Models

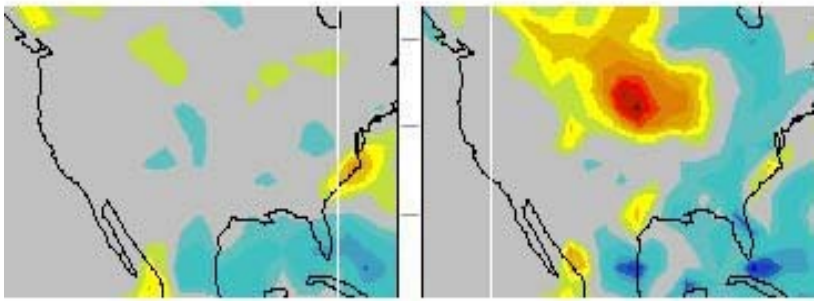
Summer 1993 Rainfall Minus Summer 1988 Rainfall

Observations

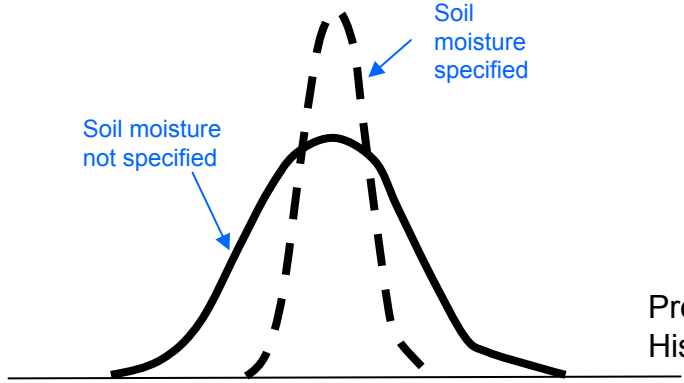


Model driven by SSTs

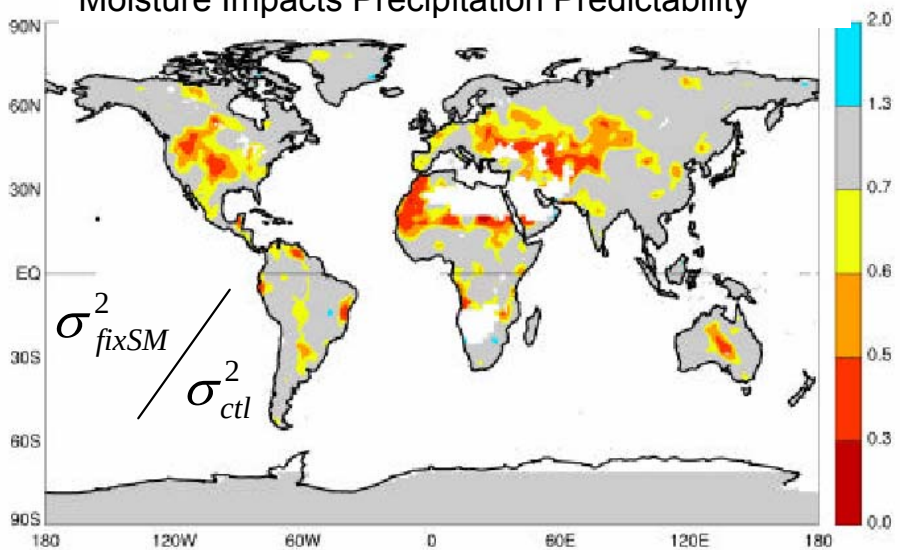
Model driven by soil moisture and SSTs



NASA GSFC GMAO Model



Multi-Model Consensus of Regions Where Soil Moisture Impacts Precipitation Predictability

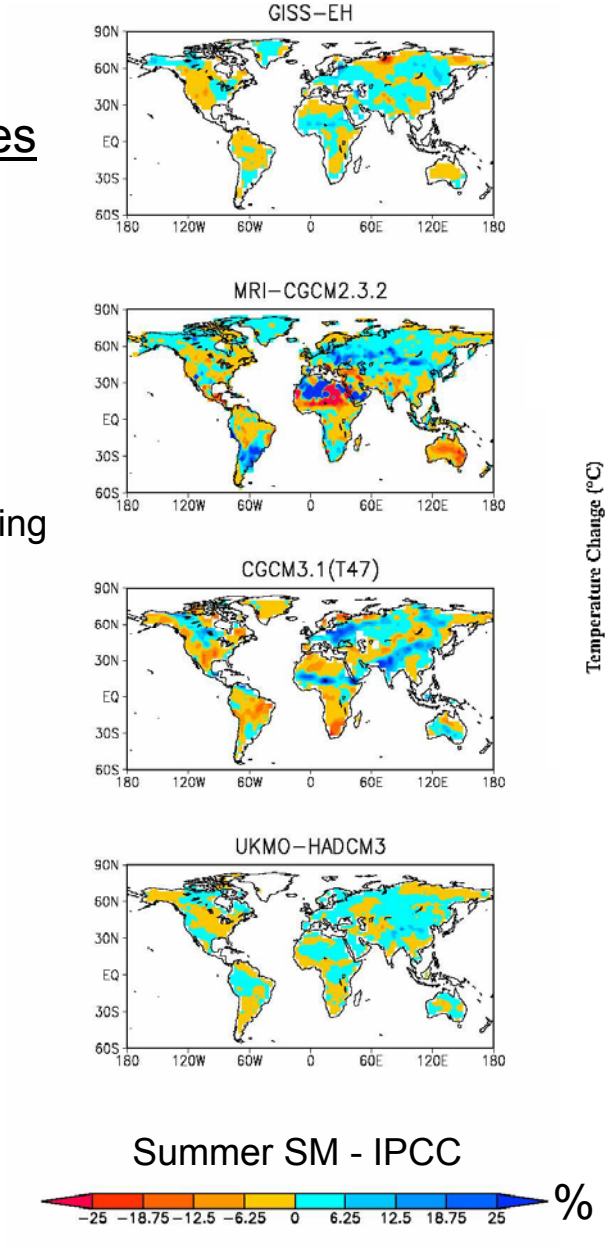


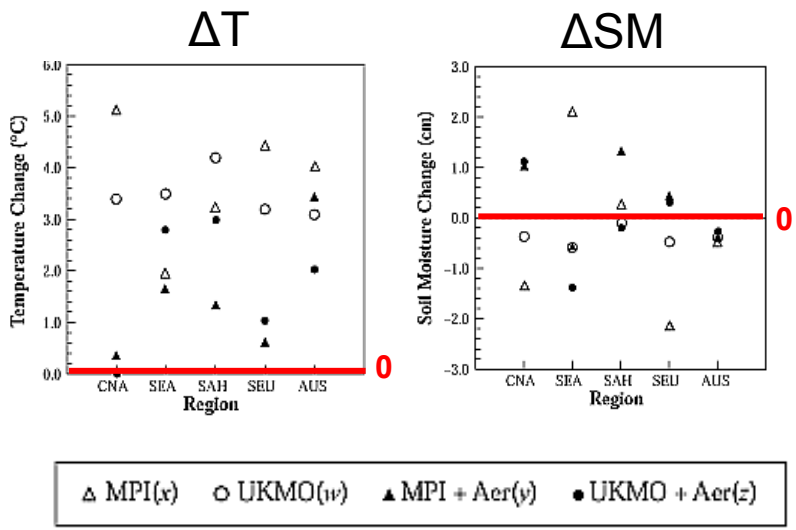
Koster et al. *Science*, 305, 2004.

Global Change and Water Cycle/Resources

"…models suited for estimating first-order changes in atmospheric temperature profiles…[are] notoriously challenged with regards to reproducing and predicting changes in atmospheric wet processes…"

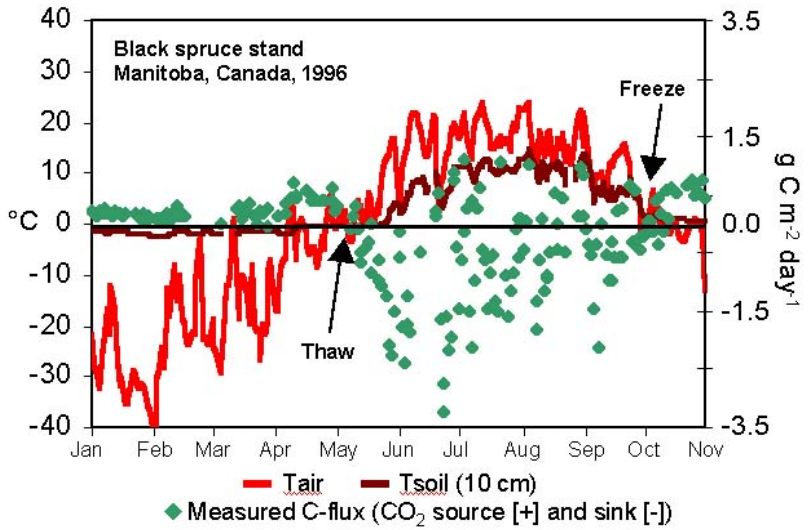
GEWEX News, 11(1)

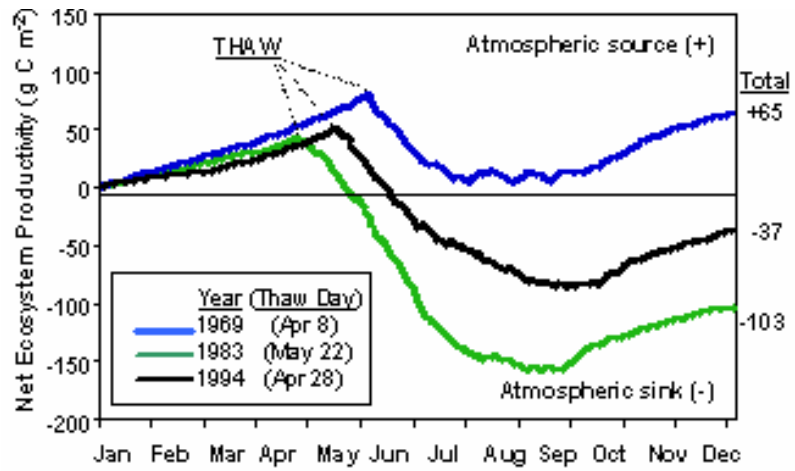


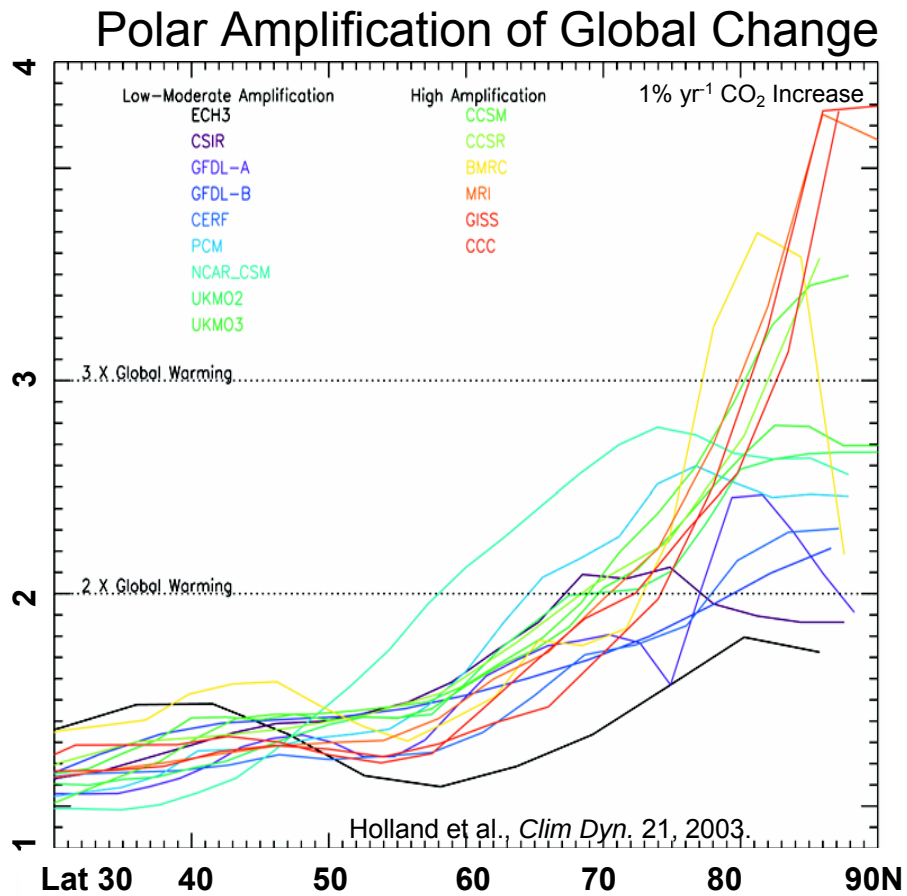


Li et al., 2007: JGR (112)

Decadal Survey: "…major source of uncertainty in assessing the carbon budget of the Earth system (… "missing carbon sink")…. In boreal latitudes, the switching on and off of the land-atmosphere carbon exchange is coincident with the freeze/thaw transitions."

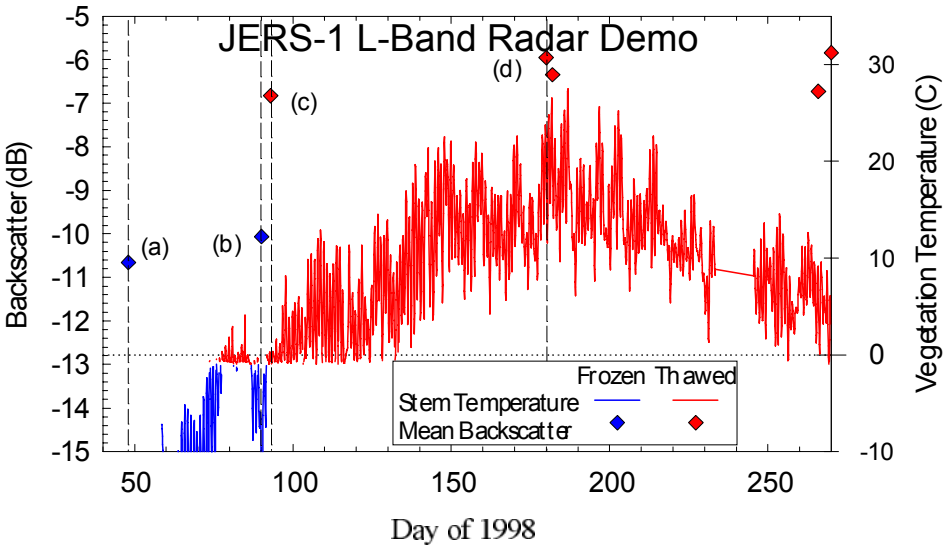






Frolking et al., *Global Change Biol*. 2, 1996.

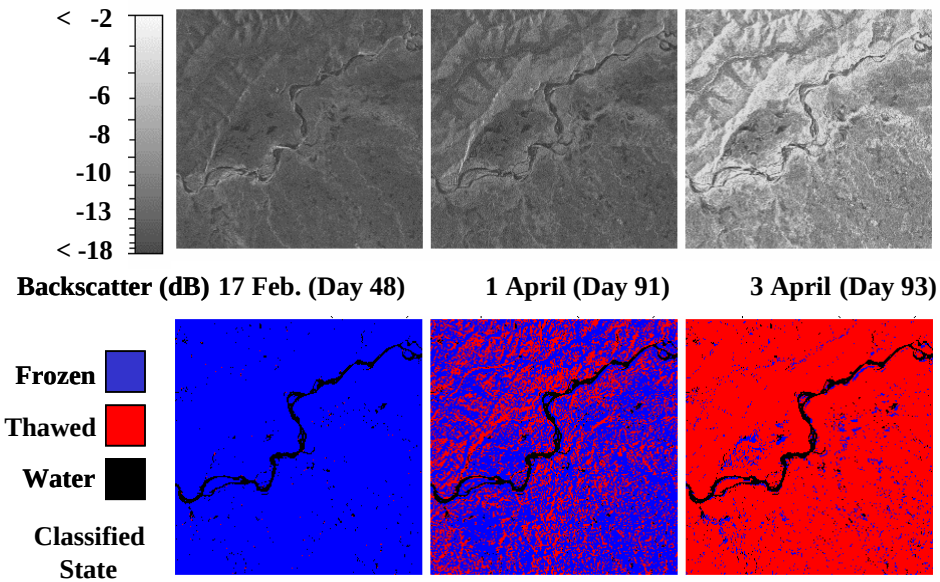
Freeze/Thaw Science Requirements



To resolve Carbon source/sink to within 0.05 [tons C ha^{-1}]*

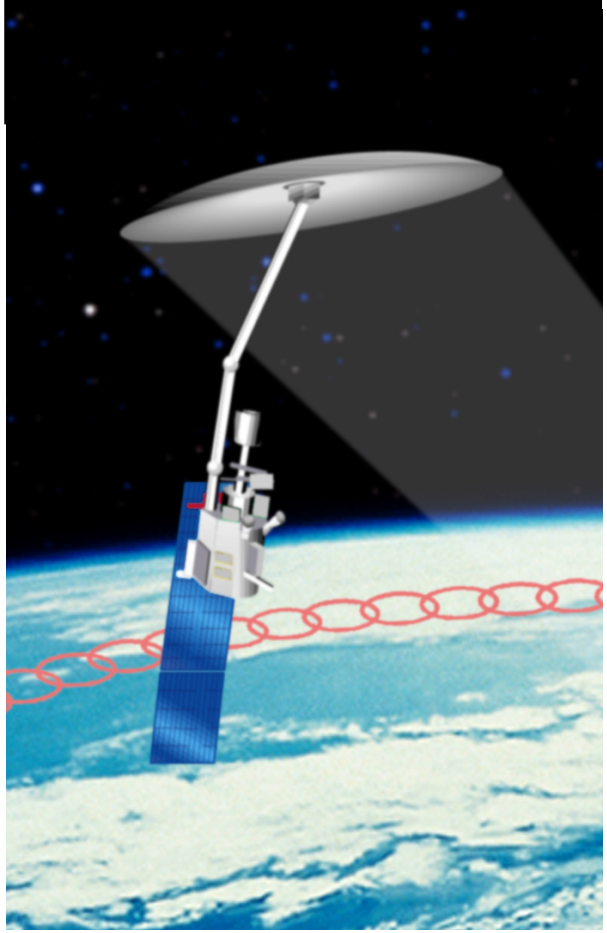
2 km resolution
1-2 day refresh
0.7 dB accuracy

JERS-1 L-band SAR landscape freeze-thaw classification



* 5 [g C m^{-2}] over 100 days

Soil Moisture Active and Passive (SMAP) Mission



Science Return: Global Views of Terrestrial Water Cycle State Variable: Soil Moisture Content and Its Freeze/Thaw State

Soil Moisture is a Variable That Links the Global Water, Energy, and Carbon Cycles

Applications Return: A New Era for the Capability to Predict Costly Natural Hazards (Extreme Weather, Floods, Droughts)

Initialization of the Soil Moisture State in Numerical Models Extends the Predictability of Processes Influenced by Surface Fluxes

National Defense Return: Global All-Weather Mapping Supports Battlespace Decision-Making and Force-Enhancement

Army Terrain Trafficability
Air Force Low-Level Fog, Dust and NWP
Navy Sea-Ice Edge and Age Assessment

Track-Record of User-Community Advocacy

Tri-Service Flag Officers (DoD)	Military Applications
Army Research Laboratory (ARL)	Army Trafficability Application
National Centers for Environmental Prediction (NCEP)	Operational Weather Prediction
European Centre for Medium-Range Weather Forecasts	Operational Weather Prediction
Meteorological Service of Canada (MSC)	Operational Weather Prediction
NASA Seasonal to Interannual Prediction Project (NSIPP)	Seasonal Climate Prediction Application
NOAA Climate Prediction Center (NOAA CPC)	Seasonal Climate Prediction Application
GEWEX Americas Prediction Project (GAPP)	Regional Water Cycle Applications
National Drought Mitigation Center (NDMC)	Drought Hazard Mitigation Application
SAHRA - Sustainability of semi-Arid Hydrology and Riparian	Water Resources Application
Office of Global Carbon Studies	Carbon Cycle Science Application
U.S. Geological Survey (USGS)	Water Resources and Flood Application
Dartmouth Flood Observatory (DFO)	Flood Monitoring Application
Center for Hydrology, Soil Climatology, and Remote Sensing	Field Site and Outreach
Boston Museum of Science	Education and Public Outreach
Global Learning and Observations to Benefit the Environment	Education

SMAP Primary Science Objectives

1. Collect space-based measurements needed to retrieve estimates of soil moisture and freeze/thaw state, for at least 3 years, over global land regions where these factors are the primary environmental controls on surface-atmosphere fluxes of water and carbon.

2. Provide estimates of soil moisture in the top 5 cm of the surface with a relative error of 4-5% volumetric, at 3-day intervals, at 10-40 km spatial resolution (hydrometeorology to hydroclimate spatial scales)

3. Provide estimates of surface freeze/thaw transitions in Boreal zones with 2-3 day relative error, at 1-3 km spatial resolution (sufficient to resolve dominant landscape heterogeneity)

4. Record, calibrate, validate, publish, and archive science data records and calibrated geophysical data products for use by the scientific community

5. Validate a space-based measurement approach and analysis concept that can be used for future systematic soil moisture and freeze/thaw monitoring missions

Requirements Traceability

Science Objectives	Scientific Measurement Requirements	Instrument Functional Requirements	Mission Functional Requirements
Enhance understanding of processes that link the water, energy and carbon cycles through monitoring the land hydrosphere state. Extend the capability of climate prediction models by providing land surface boundary data products with required resolution, global coverage, and revisit times.	Soil Moisture: ~±4% volumetric accuracy in top 2-5 cm for vegetation water content < 5 kg m^{-2}; Hydrometeorology at ~10 km; Hydroclimatology at ~40 km	L-Band Radiometer: Polarization: V, H, U; Resolution: 40 km; Relative accuracy*: 1.5 K L-Band Radar: Polarization: VV, HH, HV; Resolution: 10 km; Relative accuracy*: 0.5 dB for VV and HH Constant incidence angle** between 35° and 50°	DAAC data archiving and distribution. Field validation program. Integration of data products into multisource land data assimilation.
	Freeze/Thaw State: Capture freeze/thaw state transitions in integrated vegetation-soil continuum with two-day precision, at the spatial scale of land-scape variability (~3 km).	L-Band Radar: Polarization: HH; Resolution: 3 km; Relative accuracy*: 0.7 dB (1 dB per channel if 2 channels are used); Constant incidence angle** between 35° and 50°	
	Sample diurnal cycle at consistent time of day (6am/6pm); Global, ~3 day revisit; Boreal, ~2 day revisit	Swath Width: ~1000 km Minimize Faraday rotation (degradation factor at L-band)	Orbit: 670 km, circular, polar, sun-synchronous, ~6am/pm equator crossing
	Observation over minimum of three annual cycles	Minimum three-year mission life	Three year baseline mission***

* Includes precision and calibration stability

** Defined without regard to local topographic variation

*** From end of 30 days post-launch observatory check-out

Summary

1. SMAP Mission Data Will be Utilized Across Broad Range of Earth Science and Application Areas.

2. High-Resolution and High-Revisit Data Will be Transformational for Several Earth System (Water, Energy and Carbon Cycles) and Operational Applications.

3. Advocacy and Partnership History Stand on Strong Foundations.

4. Mission Goals and Requirements-Traceability Are Advanced.

5. Hydros Science Heritage is Substantial and Well-Documented.
    a. Level-1 Requirements and Mission Success Criteria Document
    b. Level-1 Science Requirements Document
    c. Ten Data Products Algorithm Roadmaps (pre-ATBD)